DECLARATION

I, Akinobu KOSUKEGAWA of c/o Shiga International Patent Office, 3-1, Yaesu 2 Chome, Chuo-ku, Tokyo 104-8463, Japan, understand both English and Japanese, am the translator of the English documents attached, and do hereby declare and state that the attached English documents contain an accurate translation of the priority application JP2000-046540, which was published on July 18, 2000 and that all statements made herein are true to the best of my knowledge.

Declared in Tokyo Japan
This 26th day of August, 2006

Akinobu Kosukegawa

(Title of the Document)	Patent Application
(Docket Number)	199902370
(Filing Date)	February 23, 2000
(Destination)	Commissioner, Japan Patent Office
(International Classification)	C22C 14/00
(Title of Invention)	TiA1 BASED ALLOY AND PRODUCTION METHOD THEREOF
(Number of Claims)	13

(Inventor)
(Address) c/o MITSUBISHI HEAVY INDUSTRIES, LTD., NAGASAKI Research & Development, Center, 717-1, Fukahori-machi 5-chome, Nagasaki, Nagasaki-ken
(Name) Toshimitsu TETSUI

(Inventor)
(Address) c/o MITSUBISHI HEAVY INDUSTRIES, LTD., NAGASAKI Research & Development, Center, 717-1, Fukahori-machi 5-chome, Nagasaki, Nagasaki-ken
(Name) Kentaro SHINDO

(Inventor)
(Address) c/o Tokyo Institute of Technology, 2-12-1, Ookayama, Meguro-ku, Tokyo
(Name) Masao TAKEYAMA

(Applicant for Patent)
(Identification Number) 000006208
(Name) MITSUBISHI HEAVY INDUSTRIES, LTD.

(Agent)
(Identification Number) 100112737
(Attorney)
(Name) Takaharu FUJITA

(Agent)
(Identification Number) 100064908
(Attorney)
(Name) Masatake SHIGA

(Elected Agent)
(Identification Number) 100108578
(Attorney)
(Name) Norio TAKAHASHI

(Elected Agent)
(Identification Number) 100101465
(Attorney)
(Name) Masakazu AOYAMA

(Official Fees)
(Prepayment Docket Number) 008707
(Amount of Payment) 21000

(List of Documents Submitted)
(Item) Specification 1
(Item) Drawing 1
(Item) Abstract 1
(General Power of Attorney Number) 9908282

[Document Type] Specification

[Title of the Invention] TiAl BASED ALLOY AND PRODUCTION METHOD THEREFOF

[Claims]

[Claim 1]

A TiAl based alloy having a microstructure comprising lamellar grains, being closely arranged, with a mean grain diameter of from 1 to 50 μm and with an α_2 phase and a γ phase being laminated therein alternately.

[Claim 2]

A TiAl based alloy, wherein a Charpy impact test value specified in JIS-Z2242 is 3J or higher at room temperature.

[Claim 3]

A TiAl based alloy according to claim 1, wherein a Charpy impact test value specified in JIS-Z2242 is 3J or higher at room temperature.

[Claim 4]

A TiAl based alloy according to any one of claim 1 to claim 3, comprising 42 to 48 atomic % of Al, 5 to 10 atomic % of one or more kinds selected from Cr and V, with the remainder being Ti and inevitable impurities.

[Claim 5]

A TiAl based alloy according to any one of claim 1 to claim 4, containing one or more kinds of elements selected from the group consisting of C, Si, Ni, W, Nb, B, Hf, Ta, and Zr in an amount of from 0.1 to 3 atomic % in total.

[Claim 6]

A TiAl based alloy according to any one of claim 1 to claim 5, wherein

after a TiAl based alloy material is held at a holding temperature in an α region, high-speed plastic working is applied while cooling said TiAl based alloy material to a

predetermined terminal temperature.

[Claim 7]

A TiAl based alloy according to claim 6, wherein said high-speed plastic working is a forging method.

[Claim 8]

A production method of a TiAl based alloy comprising:

a step for holding a TiAl based alloy material at a holding temperature in an α phase region; and

a step for performing high-speed plastic working on said TiAl based alloy material having been held at said holding temperature, while cooling said TiAl based alloy material to a predetermined terminal temperature.

[Claim 9]

A production method of a TiAl based alloy according to claim 8, wherein a forging method is used as said high-speed working.

[Claim 10]

A production method of a TiAl based alloy according to claim 8 or claim 9, wherein said holding temperature is between 1230 °C and 1400 °C.

[Claim 11]

A production method of a TiAl based alloy according to any one of claim 8 to claim 10, wherein said terminal temperature is 1200 °C.

[Claim 12]

A production method of a TiAl based alloy according to any one of claim 8 to claim 11, wherein said TiAl based alloy material is covered with a thermal insulation material for being held at said holding temperature, and then high-speed plastic working is performed on said TiAl based alloy material together with said thermal insulation material.

[Claim 13]

A rotor blade using a TiAl based alloy according to any one of claim 1 to claim 7.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to TiAl based alloys and a production method thereof.

[0002]

[Prior Art]

In recent years, as materials used for a turbine blade of a turbocharger, a turbine engine or the like, and materials used for future aircraft, TiAl based alloys, which are lightweight (specific gravity of about 4) and have excellent heat-resistance, are attracting much attention. In particular, in the case of a large rotor blade, the more the constituent material of the rotor blade becomes lightweight, the smaller the centrifugal stress becomes. Hence, the maximum attainable rpm and the area of the rotor blade can be increased, and load stress applied on the disk portion of the rotor blade can be reduced.

[0003]

This TiAl based alloy is an alloy composed mainly of TiAl and Ti_3Al, which is an intermetallic compound having excellent high temperature strength. As described above, it has excellent heat resistance, but has a problem such that ductility at room temperature is poor. Therefore, various measures have been heretofore taken, such as to control the structure or to add a ternary element. For example, in Japanese Unexamined Patent Application, First Publication No. Hei 6-49565, there is disclosed a technique in which Cr or V is added as the ternary element, in order to improve the ductility of the TiAl based alloy at normal temperature. Furthermore, a laminated structure (lamellar structure) region obtained by alternately laminating the TiAl phase and the Ti_3Al phase is formed in a matrix structure in order to improve the strength. Moreover, Kim (Young-Won Kim. Intermetallics. (6) 1998 pp. 623 - 628) has reported that in a TiAl alloy having lamellar grains with a mean grain diameter of from 30 to

3000 μm, as the mean grain diameter of the lamellar grains increases, the ductility and tensile stress at room temperature decrease.

[0004]

[Problems to be Solved by the Invention]

The case of the above described technique however, is not sufficient in view of improvement in ductility at room temperature. In particular, with a rotor blade used for an engine for industrial use or the like, foreign matter such as sludge may collide with the rotor blade at the time of operation, or at the time of production of the rotor blade, the rotor blade may be broken due to impact when attaching the rotor blade to the outer periphery of the disk using a hammer. Hence, it becomes necessary to improve the impact resistance of the TiAl based alloy. With the above technique however, it is difficult to improve the impact resistance.

[0005]

Furthermore, in the past, in many cases the TiAl based alloy has been produced by casting. However the casting structure is generally rough and large, and there is a tendency for the impact resistance of a material to decrease further. In the case of casting, production of small parts such as automobile parts or the like is relatively easy. However production of large parts used in ship turbines or the like has been difficult due to problems with flowability of the molten metal in the mold. On the other hand, isothermal forging is also commonly used as a forging method of the TiAl based alloy. Here, in order to develop a lamellar structure, it is necessary to pass through a zone in which the α-phase exists. With the isothermal forging, however, there is a problem such that since processing at a high temperature of 1150°C or higher is not possible due to problems of the apparatus, the lamellar structure necessary for improvement of the mechanical property is not developed in the forged material. In addition, production of large parts is also difficult.

[0006]

The present inventors have considered that it is essential to form the above described lamellar grains in the structure, in order to improve the strength of the TiAl based alloy. Based on this assumption, the present inventors have changed the mean grain diameter of the lamellar grains to various sizes, and have found that the ductility at room temperature, in particular, the impact resistance can be greatly improved for a

predetermined mean grain diameter, thereby completing the present invention.

[0007]

In addition, in order to reduce the mean grain diameter of the lamellar grains, a method is conceived such that first, a TiAl based alloy material is held in an equilibrium temperature range of an α phase, and next, high-speed plastic working is performed on the TiAl based alloy material during the succeeding cooling step. And then, a specific method has been found on this for the present invention.

[0008]

That is to say, it is an object of the present invention to solve the above described problems in the TiAl based alloy and to provide a TiAl based alloy with excellent strength as well as an improvement in ductility at room temperature, in particular, an improvement in the impact resistance at room temperature, and a production method thereof.

[0009]

[Means for Solving the Problem]

In order to achieve the above objects, the TiAl based alloy of the present invention is characterized by having a microstructure in which lamellar grains having a mean grain diameter of from 1 to 50 μm are closely arranged, with an α_2 phase and a γ phase being laminated therein alternately.

With such a construction, the strength is improved by means of the lamellar grains themselves formed in the structure, and since the lamellar grains having a small grain diameter distribute closely and finely, the structure becomes fine, and as a result, ductility at room temperature, in particular, impact resistance is improved.

[0010]

Furthermore, a TiAl based alloy of the present invention is characterized by having a Charpy impact value specified in JIS-Z2242, of 3J or higher at room temperature.

Moreover, the TiAl based alloy of the present invention is characterized by comprising 42 to 48 atomic % of Al, 5 to 10 atomic % of one or more kinds selected from Cr and V, with the remainder being Ti and inevitable impurities.

The TiAl based alloy of the present invention preferably contains one or more kinds of elements selected from the group consisting of C, Si, Ni, W, Nb, B, Hf, Ta, and

Zr in an amount of from 0.1 to 3 atomic % in total.

[0011]

The TiAl based alloy of the present invention is characterized by being produced in a method such that, after a TiAl based alloy material is held at a holding temperature in an α region, high-speed plastic working is applied while cooling this TiAl based alloy material to a predetermined terminal temperature.

The above described high-speed plastic working is preferably a forging method.

[0012]

A production method of a TiAl based alloy of the present invention comprises a step for holding a TiAl based alloy material at a holding temperature in an α phase region; and a step for performing high-speed plastic working on the TiAl based alloy material having been held at the holding temperature, while cooling this TiAl based alloy material to a predetermined terminal temperature.

With such a construction, when the TiAl based alloy material is cooled from an α phase region, distortions, which become the starting point for the occurrence of lamellar grains, are introduced into the structure by the high-speed plastic working. Accordingly, a large number of lamellar grains having a small grain diameter are formed. As a result, a fine structure can be formed.

[0013]

It is preferable to use a forging method as the above described high-speed plastic working.

Moreover, it is preferable to have a temperature of between 1230 °C and 1400 °C as the above described holding temperature.

It is preferable to have a temperature of 1200 °C as the above described terminal temperature.

[0014]

The production method of a TiAl based alloy of the present invention is characterized by performing high-speed plastic working on a TiAl based alloy material together with a thermal insulation material, after this TiAl based alloy material is covered with this thermal insulation material and is held at a holding temperature.

With such a construction, normal cold apparatus can be applied as the

apparatus for carrying out the high-speed plastic working, thereby making the apparatus simple. Moreover, since a normal die can be used and the size of the die can be freely specified, a TiAl based alloy product with a large size can be produced.

[0015]

A rotor blade of the present invention is characterized by using the above described TiAl based alloy.

[0016]

[Embodiments of the Invention]

A TiAl based alloy according to the present invention will be described referring to FIG. 1 to FIG. 3. Incidentally, FIG. 1 is a diagram of the structure of the TiAl based alloy, and FIG. 2 and FIG. 3 show photographs of the structure of the TiAl based alloy of the present invention.

[0017]

In FIG. 1, a TiAl based alloy 10 has a microstructure in which lamellar grains 2 are closely arranged, and a matrix 4 is formed between each lamellar grain 2. In the lamellar grains 2, a γ phase (TiAl) and an α_2 phase (Ti_3Al) are alternately laminated, and the lamination direction of each lamellar grain 2 is respectively different. Moreover, it is considered that since cracks occurring in the material become zigzag due to the lamellar structure, the cracks hardly progress, thereby improving the strength of the material. In addition, the matrix 4 comprises a single phase of a γ phase, an α_2 phase or a β phase, or multiple phases of each phase depending on the components of the TiAl based alloy.

[0018]

In the present invention, a feature in the structure is that the lamellar grains having a mean grain diameter of from 1 to 50 μm are closely arranged. Here, the "mean grain diameter" in the present invention is measured by a method specified in JIS-G0552. More preferably, if the lamellar grains having a mean grain diameter of from 1 to 30 μm are closely arranged, the structure becomes finer, thereby improving ductility (impact resistance) at low temperatures. Moreover, if lamellar grains having a grain diameter of 20 μm or less are contained in an amount of 40% or more among all lamellar grains, this is more preferable from the view of making the structure finer, and improving ductility (impact resistance) at low temperatures.

[0019]

"Closely arranged" in the present invention refers to a state in which when each lamellar grain is uniformly arranged in the structure, each lamellar grain comes relatively close, and specifically, it is defined as a state where the area ratio of the lamellar grains occupying in the structure is 60% or more, as seen in the cross-section view of the structure. In this case, the peripheries of lamellar grains adjacent to each other in the course of growth of each lamellar grain collide with each other or come close to each other, and the matrix 4 is forced into narrow regions between adjacent lamellar grains. As a result, the matrix 4 alone does not occupy a large area (for example, an area corresponding to a lamellar grain having a mean grain diameter of 5 μm). In addition, because of this fact, the improvement of ductility at low temperatures is also effected.

[0020]

Here, it is industrially difficult to make the mean grain diameter of the lamellar grains less than 1 μm, and if the mean grain diameter exceeds 50 μm, ductility at room temperature, and in particular, impact resistance at room temperature decreases. On the other hand, if each lamellar grain is not arranged closely, the ratio of the lamellar grains occupying in the structure decreases, and as a result, the strength is reduced. If the lamellar grains having a mean grain diameter of from 1 to 50 μm are closely formed in the structure, the strength is improved by means of the lamellar grain itself. At the same time, since lamellar grains having a small grain diameter come close to each other, the structure becomes fine, thereby improving ductility at room temperature, and in particular, impact resistance. Moreover, as described below in detail, in the present invention, cooling is performed at a predetermined cooling speed, after hot forging, and this cooling speed is higher compared to a case, such as normal heat treatment, where cooling is gradually performed in a furnace. Hence the gap between the adjacent α_2 phase and γ phase (lamellar spacing) becomes narrower. As a result, an effect that the strength is improved can be also obtained. In this case, it is preferable to make the lamellar spacing 0.5 μm or less, for example. Furthermore, when the impact resistance of the TiAl based alloy of the present invention is expressed by a Charpy impact value at room temperature, which is specified in JIS-Z2242, it is possible to make the value 3J or higher, or preferably 5J or higher.

[0021]

The composition of a TiAl based alloy 10 is not particularly restricted, but in order for the lamellar grains 2 to form stably, it is preferable that the composition contains Al in an amount of from 43 to 48 atomic % and the remainder being Ti. In particular, related with the production steps to be described below, it is preferable that the composition contains 5 to 10 atomic % of one or more elements selected from Cr and V, and the remainder being Ti and inevitable impurities. Moreover, the composition may contain, as other elements, 0.1 to 3 atomic % in total of one or more kinds selected from the group consisting of C, Si, Ni, W, Nb, B, Hf, Ta and Zr. These elements appropriately improve the high temperature strength, creep strength and oxidation resistance. In this case, if the total content of each element is less than 0.1 atomic %, the above described effects are insufficient, and if the total content of each element exceeds 3 atomic %, the effects saturate, and decrease in the impact resistance occurs, which is not desirable.

[0022]

Next, a production method of a TiAl based alloy according to the present invention will be described referring to FIG. 4 and FIG. 5. FIG. 4 is for explaining each step corresponding to a phase diagram of a binary system of TiAl, and FIGs. 5 (1) to 5 (3) show the change in the structure in each step.

[0023]

In FIG. 4, at first, the TiAl based alloy material having a predetermined composition is held at a temperature T_A within the α phase region (step A). Then, the material is subjected to high-speed plastic working, while being cooled from the holding temperature T_A to a terminal temperature T_B of the high-speed plastic working (step B). That is to say, the production method of the present invention can be said to be a kind of thermomechanical treatment, in terms of cooling the material from the α region to cause a phase transformation to a lamellar structure, and at the same time, performing plastic working. The structure formed in each of step A and B in this manner will be described based on FIGs. 5 (1) to 5 (3).

[0024]

Referring to FIGs. 5 (1) to 5 (3), in step A, the structure consists of a single phase of an α phase, and each α phase is a relatively large grain (FIG. 5 (1)). Then, in

the stage progressing from step A to step B, before reaching the ($\alpha + \gamma$) phase in the equilibrium state, that is, in the state of α single phase or structure that some γ phase is precipitated from the α phase, high-speed plastic working is performed immediately, and at this time, a large number of distortions t are introduced into the structure. Then, with these distortions t as a starting point, the γ phase is also precipitated from the α phase. Hence a large number of lamellar grains 2 are formed in the structure (FIG. 5 (2)). Then, before each lamellar grain 2 is fully grown, grain growth is hindered at a point of time when the adjacent lamellar grains 2 compete. As a result, a fine structure in which a large number of lamellar grains 2 having a small grain diameter cluster together can be obtained. In addition, in step B, the remaining α phase is changed into the α_2 phase, and lamellar grains with the α_2 phase and the γ phase being laminated alternately are formed (FIG. 5 (3)).

[0025]

Here, in the high-speed plastic working described above, since the material undergoes deformation under a high rate of distortion, it is necessary to keep the material at as high a temperature as possible in order to increase the deformation capacity. Accordingly, it is preferable to increase the terminal temperature T_B of the plastic working to 1200 °C or higher. If the terminal temperature T_B of the plastic working is less than 1200 °C, the material temperature at the time of working decreases, and hence the deformation capacity decreases. This may cause cracks in the material. Moreover, if the cooling speed from the α phase is too fast, massive transformation occurs, and the lamellar phase is not formed. If the cooling speed is too slow, the lamellar spacing expands to decrease the strength, which is not desirable. Therefore, it is preferable to set the cooling speed to, for example, about 50 to 700 °C/min., in order that a lamellar structure having narrow lamellar spacing is formed.

[0026]

As the high-speed plastic working, for example, forging or rolling may be used. In this case, if a material to be processed is taken out from a furnace after being held in the furnace at a predetermined holding temperature, the material cools quickly. Therefore, it may be difficult to keep the temperature of the material at 1200 °C or higher until completion of working, depending on the size of the material to be processed. Accordingly, in such a case, apparatus for normal working can be directly

used by applying a production method shown in FIGs. 9 (1) to 9 (3).

[0027]

In the figure, a TiAl based alloy material 8 is first prepared (FIG. 6 (1)). As this TiAl based alloy material 8, any material may be used, such as cast material, wrought material (isothermal forging material, hot working material) or the like.

[0028]

Next, the TiAl based alloy material 8 is covered with a thermal insulation material 20, and a cover 22 for supporting the thermal insulation material 20 is attached on the outside of the thermal insulation material 20. In this state, the material 8 is held in a furnace or the like, in which the temperature is kept at a holding temperature of the α phase region (step A' in FIG. 6 (2)). The thermal insulation material 20 is for keeping the TiAl based alloy material 8 taken out from the furnace at a high temperature until completion of high-speed plastic working, and for keeping a predetermined cooling speed and preventing the material temperature from decreasing. The thermal insulation material 20 and the cover 22 are worked together with the TiAl based alloy material 8. Therefore, as the thermal insulation material 20, a soft material such as SiO_2 or the like into a plate form or a cotton form is used, and as the cover 22, a sheet material or the like made of a steel which is easily plastically deformed is used.

[0029]

Then, the TiAl based alloy material 8 is taken out from the furnace together with the thermal insulation material 20 and the cover 22, and set up between an upper mold 30A and a lower mold 30B of a forging apparatus used for normal forging to be subjected for forging (step B' in FIG. 6 (3)). At the time of forging, the TiAl based alloy material 8 taken out from the furnace is covered with the insulation material 20 and is kept at a temperature close to the in-furnace temperature. As a result, the occurrence of forging cracks or the like is prevented, and phase transformation is caused to occur at an adequate cooling speed, and hence the lamellar grains are stably formed. In this manner, the final product (TiAl based alloy 10) having a structure shown in FIG. 5 (3) is obtained (FIG. 6 (4)). Here, appropriate post-processing, heat treatment or the like may be applied to this final product.

[0030]

As described above, if the production method shown in FIGs. 6 (1) to 6 (4) is

adopted, a normal cold forging apparatus can be applied to the forging apparatus (and upper mold 30A, lower mold 30B), making the apparatus simple. Moreover, since it is not necessary to use a special heat resistant die (for example, Mo alloy such as TZM) as in isothermal forging which has heretofore been performed with respect to the TiAl based alloy, a normal die can be used and the size of the die can be freely set. As a result, a large sized TiAl based alloy product can be produced. Here, forging has been described above as an example, but the present invention is not limited thereto, and for example, rolling may be performed. In this case, a sheet form TiAl based alloy can be produced.

[0031]

Incidentally, with the TiAl based alloy of a binary system, mechanical properties become favorable at Al concentrations of from 45 to 48 atomic %. As shown in FIG. 4 however, the temperature in the α phase region of the TiAl based alloy having such a component exceeds 1300 °C, and it may be industrially difficult to hold the material at this temperature due to limitations in the performance of the heating furnace. Therefore, in such a case, the composition of the TiAl based alloy is changed, and the equilibrium temperature range of the α phase is decreased, utilizing the change of the phase diagram. Specifically, it is preferable to use a TiAl based alloy of a ternary system, comprising 42 to 48 atomic % of Al, 5 to 10 atomic % of one or more kinds selected from Cr and V, with the remainder being Ti and inevitable impurities. FIG. 7 shows the phase diagram of this ternary system. In addition, the region represented by the broken line in the phase diagram of the figure shows the case for Ti-Al-Cr alloy (Cr : 10 atomic %), and the region represented by the solid line in the figure shows the case for Ti-Al-V alloy (V : 10 atomic %).

[0032]

In FIG. 7, the lowest temperature in the equilibrium region of the α phase of the Ti-Al-Cr alloy is about 1250 °C, and the α phase exists as a stable phase above this temperature. Moreover, the lowest temperature in the α phase region of the Ti-Al-V alloy is about 1150 °C, and the α phase exists as a stable phase above this temperature. Therefore, if a ternary system TiAl based alloy containing the above described respective components is used, the holding temperature of the α phase in the equilibrium region can be made to be 1300 °C or less. Hence this is industrially

advantageous in that a general heating furnace can be used.

[0033]

Furthermore, these ternary TiAl based alloys have a characteristic that the β phase is precipitated in addition to the γ phase at the lower temperature side than the α phase region. However, since the γ phase is first precipitated from the α phase, the finally formed structure is almost the lamellar structure. FIG. 2 and FIG. 3 described above show the structure which is obtained by the high-speed plastic working according to the method of the present invention performed after a Ti-Al-V alloy material (45 atomic % of Al, 10 atomic % of V) is held at a holding temperature of 1250 °C. In this case, lamellar grains occupy almost all of the structure, but the β phase can be recognized in very small parts (white phase in the figure). In the above described example, description has been made of a case where either of Cr or V is added. However, both of Cr and V, whose total amount is from 5 to 10 atomic %, may be added. In addition, since the Ti-Al-Cr type alloy is more excellent in high temperature properties than the Ti-Al-V type alloy, it is better that the former is used for high temperature applications (for example, for turbine rotor blades of gas turbines), and the latter is used for low temperature application (for example, for turbine rotor blades of turbine engines for ships). FIG. 8 shows the external shape of the rotor blade described above.

[0034]

In this rotor blade shown in FIG. 8, the rotor blade 50 comprises a profile 50A and a root 50B. The root 50B is driven into a slot on the outer periphery of a disc shaped disk to constitute the whole turbine rotor. In addition to the above described rotor blade 50, the disk itself may be produced by using the TiAl based alloy of the present invention.

[0035]

[Examples]

1. Manufacture of a TiAl based alloy material

After a TiAl based alloy having a composition of 45 atomic % of Al, 10 atomic % of V, with the remainder being Ti and inevitable impurities was melted by a plasma skull method, the TiAl based alloy was cast to an ingot, and then appropriately cut out and subjected to surface finishing, to thereby obtain an ingot material in a

columnar shape having a diameter of 95 mm and a length of 109 mm.

[0036]

2. Heat insulation treatment of the material

Next, this ingot material was covered with a thermal insulation sheet made of Isowool (mixture of alumina and silica) having a thickness of 3 mm, and further the outside of the thermal insulation sheet was covered with a cover made of Cr-Mo steel. The outer diameter including the cover was 115 mm. This heat insulation sheet had a thermal insulation performance such that the time for cooling an object held at 1250 °C to 1200 °C was 3 minutes.

[0037]

3. Pre-working of the material (extrusion)

This ingot material with the cover was held in a furnace at 1250 °C for 1 hour, and then taken out from the furnace and subjected to one pass extrusion (extruding speed: 30 mm/s). Extrusion was performed in 30 seconds after taking out from the furnace. The size of the extruded material itself was 40 mm diameter x 300 mm, and the outer size including the cover was 48 mm diameter x 320 mm.

[0038]

4. High-speed plastic working (forging)

The thermal insulation sheet and cover which covered the above described extruded material were removed and the surface of the extruded material was smoothed. Then, the thermal insulation sheet and the cover were attached again to the extruded material in the same manner as described above, and was held at 1250 °C for 1 hour, and then taken out and forged into a predetermined shape by a cold press of 2800 tons so that the thickness of the extruded material itself became 10 mm to make it flat. Forging was performed in 30 seconds after taking out from furnace, and the material was air-cooled and left after being forged, to thereby obtain a sample of lamellar grains having a mean grain diameter of 4 μm.

[0039]

As a comparison, Ti-47Al-2Cr-2Nb (atomic %) alloy was melted by a plasma skull melting, to obtain an ingot having the same size as above, and this ingot was subjected to isothermal forging at 1100 °C, until it had a thickness of one fourth of the initial thickness. Thereafter, the ingot was heat treated at 1400 °C for 10 minutes, to

obtain a sample of lamellar grains having a mean grain diameter of 100 μm. This was designated as Comparative Example 1. In addition, one obtained by casting Ti-47Al-2Cr-2Nb (atomic %) alloy was designated as Comparative Example 2. Moreover, one obtained by casting using Inconel 713C was designated as Comparative Example 3. FIG. 9 and FIG. 10 show the photographs of the structure of Comparative Example 2.

[0040]

3. Property evaluation of samples after forging

Tensile strength of each sample material was measured by an ordinary method at room temperature and at a high temperature (700 °C). Moreover, these sample materials were subjected to the Charpy impact testing specified in JIS-Z2242 at room temperature. Respective results are shown in Table 1 and Table 2.

[Table 1]

[Table 2]

[0041]

As is obvious from Table 1 and Table 2, both the tensile strength and the Charpy impact test value on Example at room temperature and 700 °C are excellent.

[0042]

On the other hand, in Comparative Example 1 and Comparative Example 2 where the mean grain diameter of lamellar grains are 100 μm and 150 μm respectively, both the tensile strength and the Charpy impact value at room temperature decrease considerably. In the case of Comparative Example 3 comprising Inconel 713C, even though this is excellent in the Charpy impact value at room temperature, the tensile strength is low, and since the specific gravity is twice as large as the TiAl based alloy, the specific strength (strength / specific gravity) required as a rotating part further decreases.

[0043]

[Effects of the Invention]

As is clear from the above descriptions, in a TiAl based alloy according to the present invention, lamellar grains having a small diameter are closely arranged. As a result, the structure becomes fine, and strength as well as toughness at room temperature, and in particular, impact resistance is improved.

[0044]

Furthermore, in a production method of a TiAl based alloy according to the present invention, when a TiAl based alloy material is cooled from an α phase region, distortions, which become the starting point for the occurrence of lamellar grains, are introduced into the structure by high-speed plastic working. In addition, the cooling is performed with a suitable cooling speed until completion of the working, and as a result, a large number of lamellar grains with a small grain diameter and small lamellar spacing are formed. Hence, a fine structure can be made.

[0045]

In particular, after a TiAl based alloy material covered with a thermal insulation material is maintained at a holding temperature, high-speed plastic working is performed on this TiAl based alloy material together with the thermal insulation material. Accordingly, normal cold apparatus can be applied as the apparatus for carrying out the high-speed plastic working. As a result, TiAl based alloys can be produced with considerably lower cost when compared with a constant temperature forging method being used as a forging method for conventional TiAl based alloys.

[Brief Description of the Drawings]

[Figure 1]

FIG. 1 is a diagram showing a structure of a TiAl based alloy according to the present invention.

[Figure 2]

FIG. 2 is a photograph substituting a drawing showing a structure of the TiAl based alloy according to the present invention.

[Figure 3]

FIG. 3 is a photograph substituting a drawing showing a structure of the TiAl based alloy according to the present invention.

[Figure 4]

FIG. 4 is a TiAl based alloy binary phase diagram containing corresponding production steps of the TiAl based alloy of the present invention for an explanation purpose.

[Figure 5]

FIGs. 5 (1) to 5 (2) are diagrams showing the change in the structure in each production step.

[Figure 6]

FIGs. 6 (1) to 6 (4) are process diagrams showing a method of producing a TiAl based alloy of the present invention by using a thermal insulation material and a cover.

[Figure 7]

FIG. 7 is a phase diagram of a TiAl based alloy in a ternary compound system of the present invention.

[Figure 8]

FIG. 8 is a perspective view showing a rotor blade of the present invention.

[Figure 9]

FIG. 9 is a photograph substituting a drawing showing a structure of Comparative Example 2.

[Figure 10]

FIG. 10 is a photograph substituting a drawing showing a structure of Comparative Example 2.

[Brief Description of the Reference Symbols]

2 : LAMELLAR GRAIN

4 : MATRIX

8 : TiAl BASED ALLOY MATERIAL

10 : TiAl BASED ALLOY

20 : THERMAL INSULATION MATERIAL

22 : COVER

30A : UPPER MOLD

30B : LOWER MOLD

50 : ROTOR BLADE

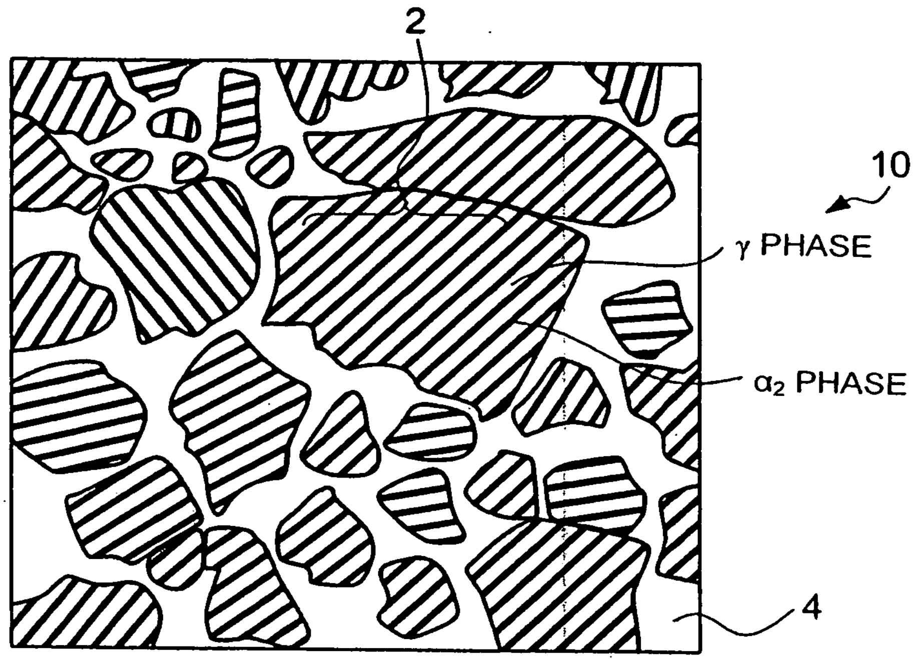
[Table 1]

	Mean grain diameter of lamellar grain (μm)	Tensile str. (MPa)	
		Room temp.	High temperature
Example	4	1082	1245 (700 °C)
Comp. Ex. 1	100	673	686 (700 °C)
Comp. Ex. 2	150	494	530 (700 °C)
Comp. Ex. 3	-	847	890 (700 °C)

[Table 2]

	Mean grain diameter of lamellar grain (μm)	Charpy impact value (J)
Example	4	5
Comp. Ex. 1	100	1
Comp. Ex. 2	150	1
Comp. Ex. 3	-	12

FIG. 1



2: LAMELLAR GRAIN
4: MATRIX
10: TiAl BASED ALLOY

FIG. 2

FIG. 3

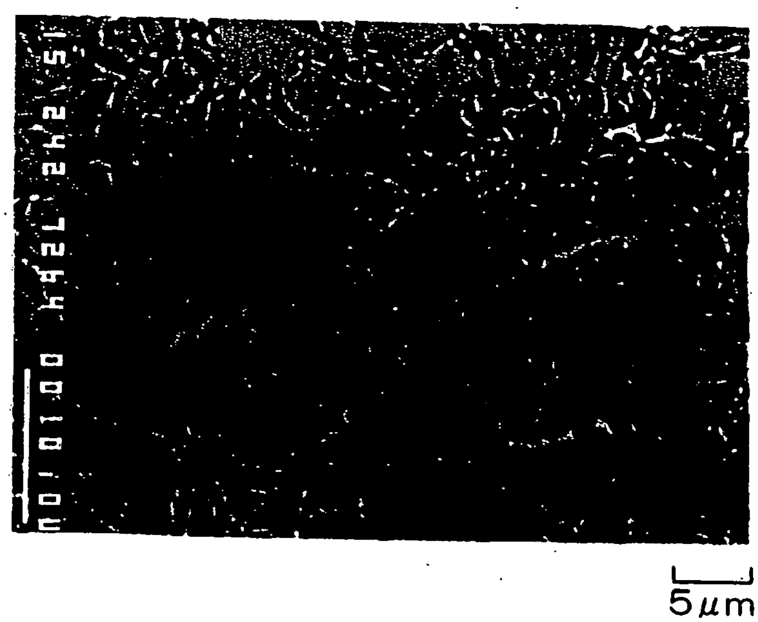
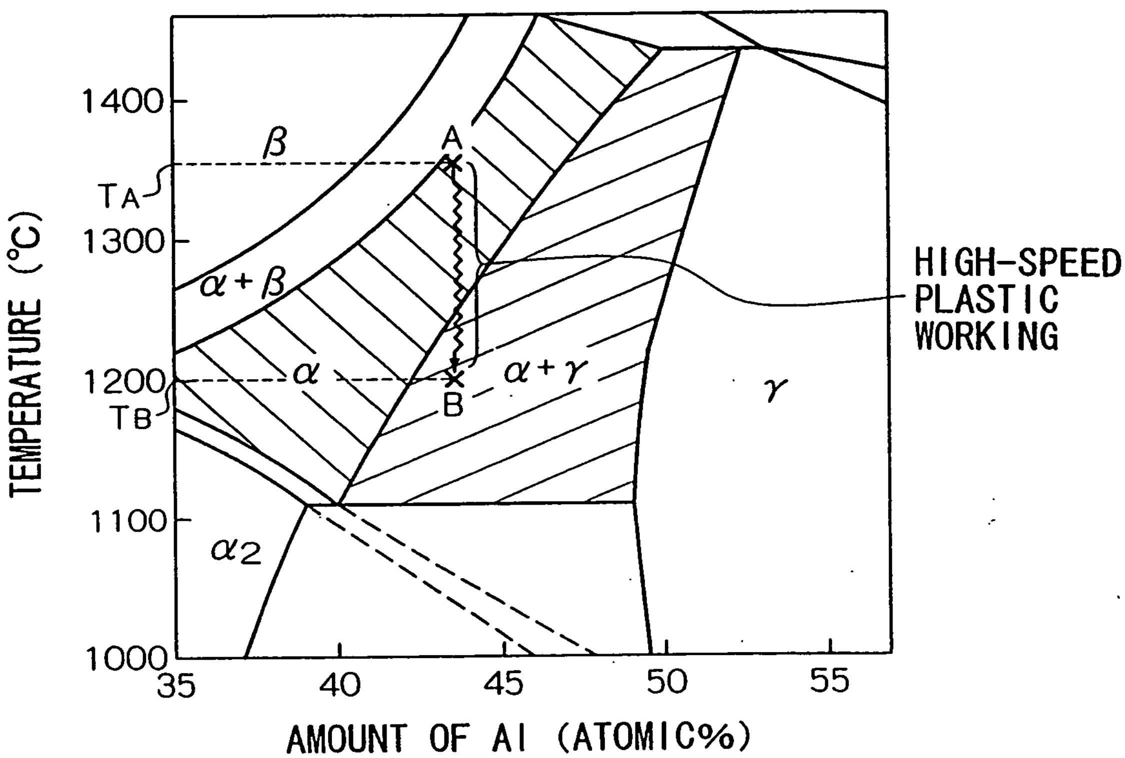


FIG. 4



1400
1300
1200
1100
1000
TEMPERATURE (°C)
TA
TB
β
α+β
α
α+γ
γ
α2
A
B
HIGH-SPEED
PLASTIC
WORKING
35
40
45
50
55
AMOUNT OF Al (ATOMIC%)

FIG. 5

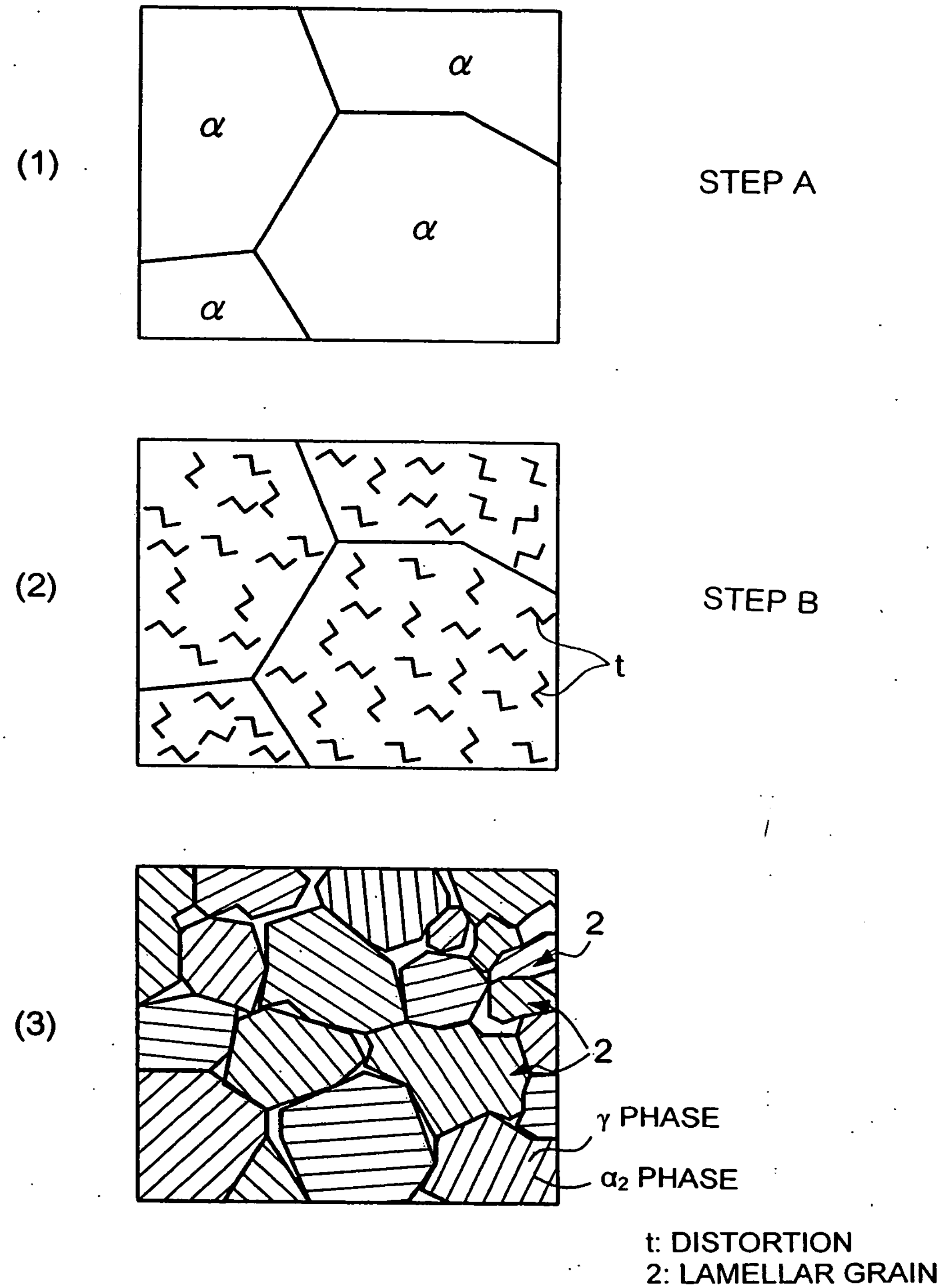
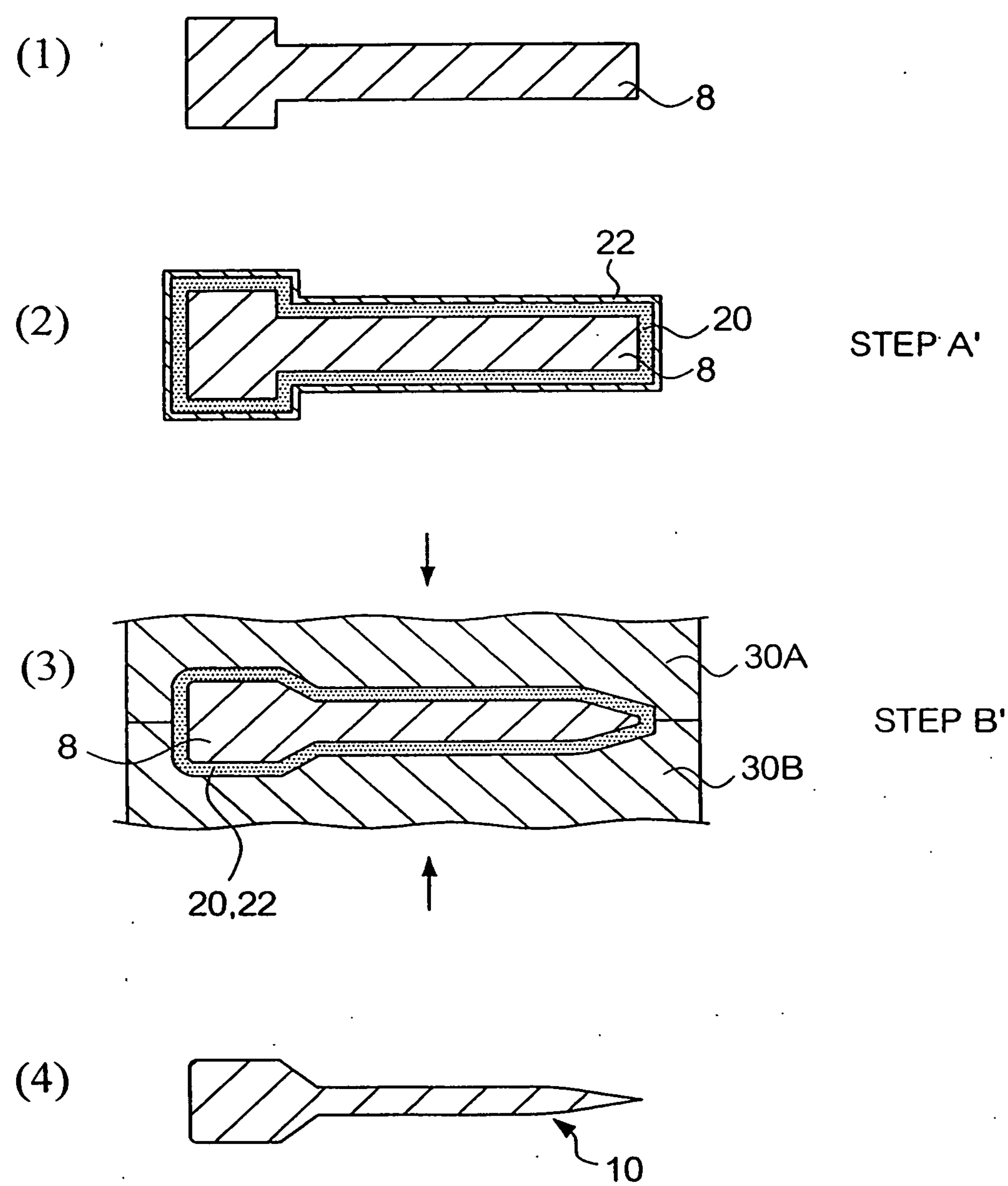
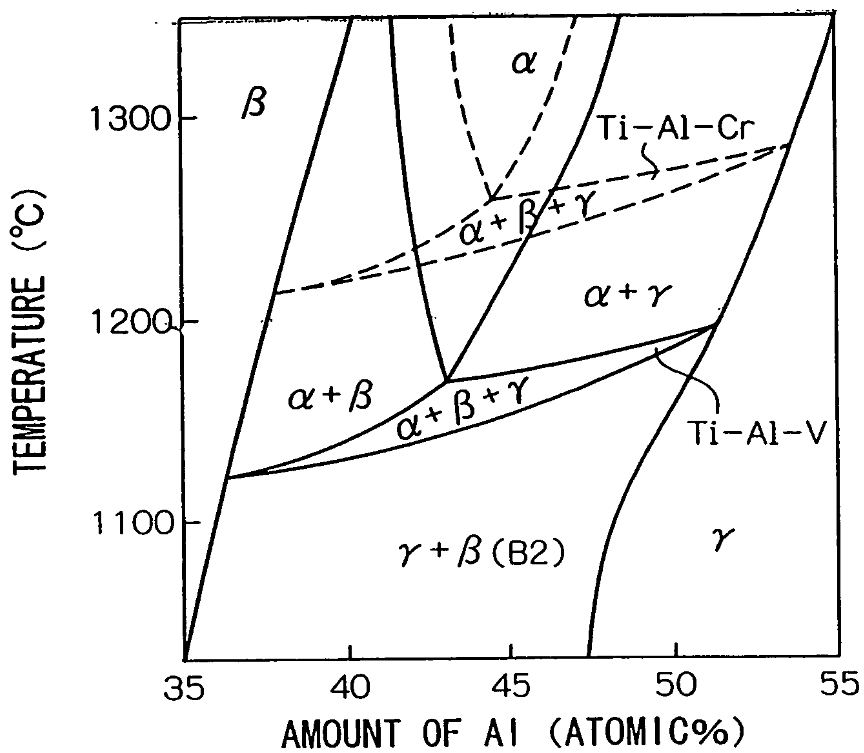

(1)
α
α
α
α
STEP A
(2)
STEP B
t
(3)
2
2
γ PHASE
α2 PHASE
t: DISTORTION
2: LAMELLAR GRAIN

FIG. 6



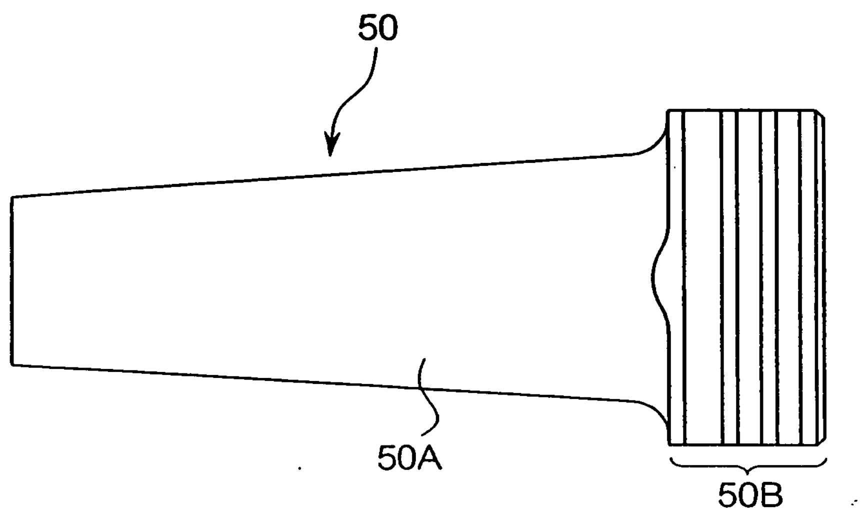
8: TiAl BASED ALLOY MATERIAL
10: TiAl BASED ALLOY
20: THERMAL INSULATION MATERIAL
22: COVER
30A: UPPER MOLD
30B: LOWER MOLD

FIG. 7



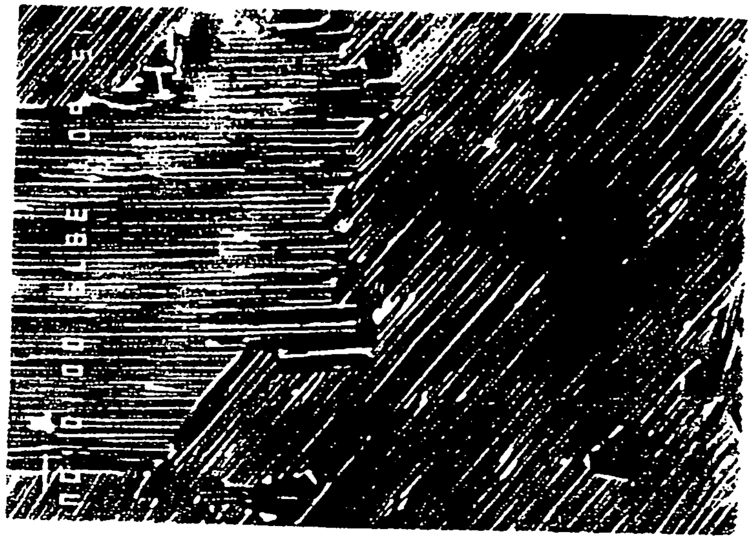
β
α
Ti-Al-Cr
α+β+γ
α+γ
α+β
α+β+γ
Ti-Al-V
γ+β (B2)
γ
1300
1200
1100
TEMPERATURE (°C)
35
40
45
50
55
AMOUNT OF Al (ATOMIC%)

FIG. 8



50: ROTOR BLADE
50A: PROFILE
50B: ROOT

FIG. 9



20 μm

FIG. 10

5 μm

[Document Type] Abstract

[Abstract]

[Problem to be Solved by the Invention]

To provide a TiAl based alloy having an excellent strength as well as an improvement in ductility at room temperature, in particular an improvement in impact resistance at room temperature, and a production method thereof.

[Means for Solving the Problem]

To provide a microstructure comprising lamellar grains, being closely arranged, with a mean grain diameter of from 1 to 50 μm and with an α_2 phase and a γ phase being laminated therein alternately.

[Elected Drawing] FIG. 1